Claims

1. A method of electrowinning copper comprising:

providing an electrochemical cell comprising at least one anode and at least one cathode, wherein said cathode has an active surface area;

providing a flow of electrolyte through said electrochemical cell, said electrolyte comprising copper and solubilized ferrous iron;

oxidizing at least a portion of said solubilized ferrous iron in said electrolyte at the at least one anode from ferrous iron to ferric iron;

removing at least a portion of said copper from said electrolyte at the at least one cathode; and

operating said electrochemical cell at a cell voltage and at a current density, wherein said cell voltage is less than about 1.5 Volts and wherein said current density is greater than about 26 amperes per square foot of active cathode.

2. The method according to claim 1, further comprising operating said electrochemical cell at a current density of from about 20 to about 50 amperes per square foot of active cathode.

3. The method according to claim 1, further comprising operating said electrochemical cell at a current density greater than about 30 amperes per square foot of active cathode.

4. The method according to claim 1, wherein operating said electrochemical cell at a cell voltage comprises operating said electrochemical cell at a cell voltage of less than about 1.2 Volts.

5. The method according to claim 1, wherein operating said electrochemical cell at a cell voltage comprises operating said electrochemical cell at a cell voltage of less than about 1.0 Volts.

6. The method according to claim 1, wherein said step of providing a flow of electrolyte through said electrochemical cell comprises providing an electrolyte flow rate of from about 0.1 to about 1.0 gallons per minute per square foot of active cathode.

7. The method according to claim 1, wherein said step of providing a flow of electrolyte through said electrochemical cell comprises providing an electrolyte flow rate of from about 0.1 to about 0.25 gallons per minute per square foot of active cathode.

8. The method according to claim 1, wherein said step of oxidizing comprises oxidizing at least a portion of said solubilized ferrous iron in said electrolyte at a flow-through anode.

9. The method according to claim 8, wherein said step of oxidizing comprises oxidizing at least a portion of said solubilized ferrous iron in said electrolyte at an anode comprising titanium mesh having an electrochemically active coating.

10. The method according to claim 1, wherein said step of providing a flow of electrolyte comprises providing a flow of electrolyte having an iron concentration of from about 10 g/L to about 60 g/L.

11. The method according to claim 1, wherein said step of providing a flow of electrolyte comprises providing a flow of electrolyte having an iron concentration of from about 20 g/L to about 60 g/L.

12. The method according to claim 1, wherein said step of providing a flow of electrolyte further comprises maintaining the temperature of said electrolyte in the range of from about 110°F to about 180°F.

13. The method according to claim 1, wherein said step of providing a flow of electrolyte further comprises maintaining the temperature of said electrolyte above about 115°F.

14. The method according to claim 1, wherein said step of providing a flow of electrolyte further comprises maintaining the temperature of said electrolyte below about 150°F.

15. The method according to claim 1, further comprising:

removing at least a portion of said ferric iron from said electrochemical cell in an electrolyte regeneration stream;

reducing at least a portion of said ferric iron in said electrolyte regeneration stream to ferrous iron to form a regenerated electrolyte stream; and

returning at least a portion of said regenerated electrolyte stream to said electrochemical cell.

16. The method according to claim 15, wherein said step of reducing at least a portion of said ferric iron comprises contacting said ferric iron with a reducing agent in the presence of a catalyst.

17. The method according to claim 9, wherein said step of reducing at least a portion of said ferric iron comprises contacting said ferric iron with sulfur dioxide gas in the presence of a catalyst.

18. A process for electrowinning copper from a copper- and ferrous iron-containing electrolyte stream comprising providing an electrochemical cell comprising at least one anode and at least one cathode, wherein ferrous iron is oxidized at the anode to form ferric iron and copper is plated at the cathode and wherein said cathode has an active surface area,

the improvement comprising providing at least one flow-through anode and effectively circulating said electrolyte within said electrochemical cell, such that operation of said electrochemical cell can be conducted at a cell voltage of less than about 1.5 Volts and a current density in excess of 26 amperes per square foot of active cathode.

19. The process according to claim 18, wherein the improvement further comprises facilitating effective electrolyte circulation by providing a flow of electrolyte through said electrochemical cell at a flow rate of from about 0.1 to about 0.25 gallons per minute per square foot of active cathode.

20. The process according to claim 18, wherein the improvement further comprises facilitating effective electrolyte circulation by providing a flow of electrolyte through said electrochemical cell using an electrolyte flow manifold.

21. The process according to claim 18, the improvement further comprising injecting at least a portion of said electrolyte into said at least one flow-through anode.

22. The process according to claim 18, the improvement further comprising operating said electrochemical cell at a current density of greater than about 30 amperes per square foot of active cathode.

23. The process according to claim 18, the improvement further comprising removing at least a portion of said ferric iron from said electrochemical cell in an electrolyte regeneration stream;

reducing at least a portion of said ferric iron in said electrolyte regeneration stream to ferrous iron to form a regenerated electrolyte stream; and

returning at least a portion of said regenerated electrolyte stream to said electrochemical cell.

24. The process according to claim 23, wherein said step of reducing at least a portion of said ferric iron comprises contacting said ferric iron with a reducing agent in the presence of a catalyst.

25. The process according to claim 23, wherein said step of reducing at least a portion of said ferric iron comprises contacting said ferric iron with sulfur dioxide gas in the presence of a catalyst.

26. A system for electrowinning copper from a copper-containing electrolyte, comprising:

an electrolyte stream, wherein said electrolyte stream comprises copper and iron, and wherein the concentration of iron in said electrolyte stream is from about 10 to about 60 grams per liter;

an electrochemical cell, wherein said electrochemical cell comprises at least one anode, at least one cathode, and an electrolyte flow manifold, and wherein said at least one anode comprises at least one flow-through anode.

27. The system according to claim 26, wherein said electrolyte stream comprises ferrous iron and ferric iron, and wherein the concentration of ferric iron in said electrolyte stream is from about 0.001 to about 10 grams per liter.

28. The system according to claim 26, wherein said electrolyte stream comprises ferrous iron and ferric iron, and wherein the concentration of ferric iron in said electrolyte stream is from about 1 to about 6 grams per liter.

29. The system according to claim 26, wherein said electrolyte stream comprises ferrous iron and ferric iron, and wherein the concentration of ferric iron in said electrolyte stream is from about 2 to about 4 grams per liter.

30. The system according to claim 26 further comprising means for reducing at least a portion of said ferric iron in said electrolyte stream to ferrous iron by contacting said ferric iron with sulfur dioxide gas in the presence of a catalyst.

31. The system according to claim 26, wherein said electrochemical cell comprises at least one anode comprising a metal mesh having an electrochemically active coating.

32. The system according to claim 31, wherein said electrochemical cell comprises at least one anode comprising titanium mesh having an iridium-oxide based coating.

33. The system according to claim 31, wherein said electrochemical cell comprises at least one anode comprising titanium mesh having a ruthenium-oxide based coating.

34. The system according to claim 26, further comprising an effective amount of plating reagent.

35. The system according to claim 34, wherein said plating reagent comprises at least one of thiourea, guar gum, modified starch, polyacrylic acid, polyacrylates, chloride ion, and mixtures thereof.

36. The system according to claim 26, wherein said electrolyte flow manifold is configured to inject electrolyte into said anode.

37. The system according to claim 26, wherein said electrolyte flow manifold is configured to maintain an electrolyte flow rate to the cell of from about 0.1 to about 1.0 gallons per minute per square foot of active cathode.